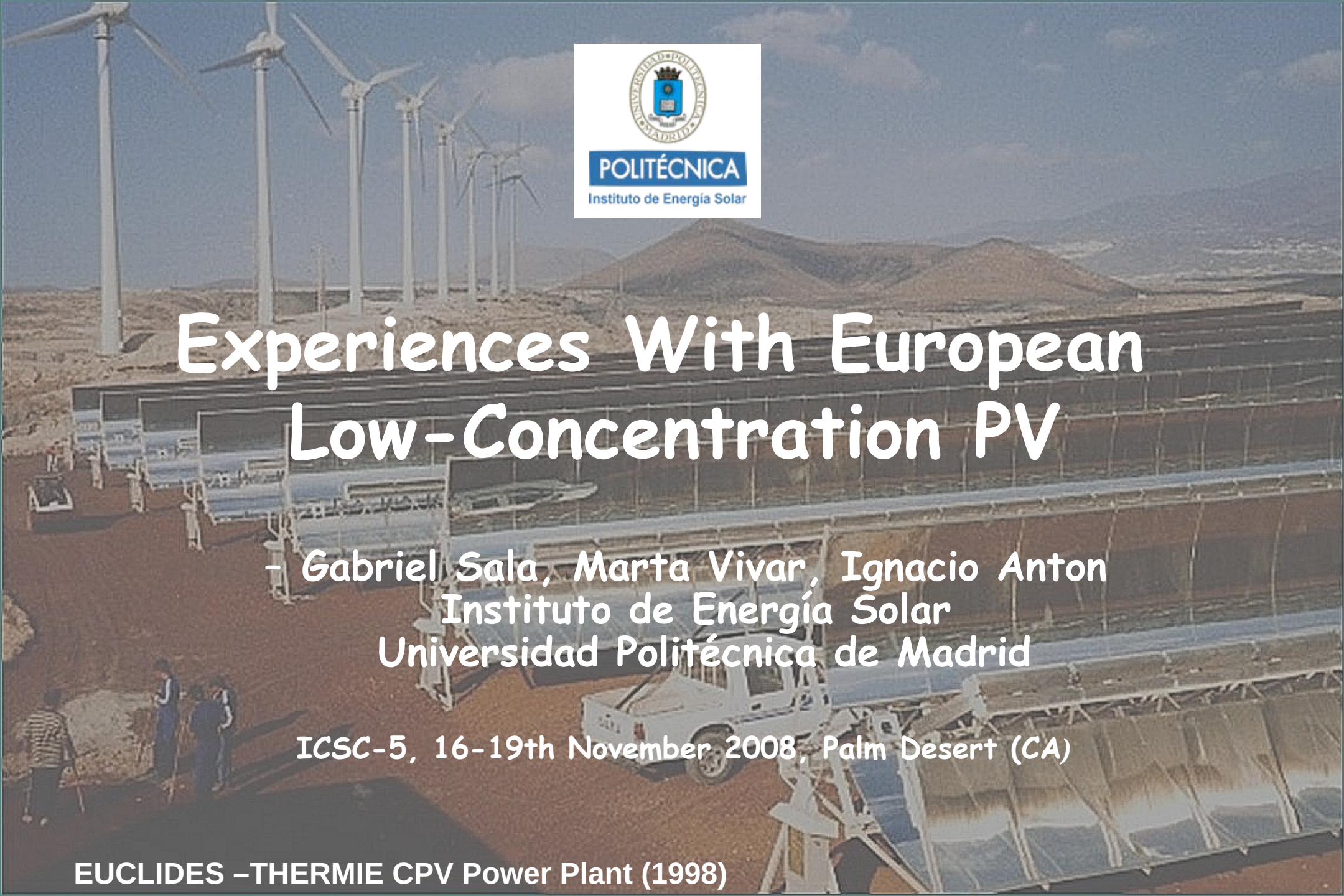

Experiences With European Low-Concentration PV

- Gabriel Sala, Marta Vivar, Ignacio Anton
Instituto de Energía Solar
Universidad Politécnica de Madrid

ICSC-5, 16-19th November 2008, Palm Desert (CA)

EUCLIDES –THERMIE CPV Power Plant (1998)

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What is Low Concentration PV?

- We could agree that **geometrical gain between 2X to 50X** defines the PV Low Concentration **range.**

- We could discriminate between:
  - **2X - 10X into LOW CPV**
  - **10X- 50X into MEDIUM CPV**

    - The limit for LOW is 10X because diffuse light contribution becomes negligible at that level.
    - The limit for MEDIUM is 50X because the gain in single axis tracking (with one stage) is practically limited to this value.

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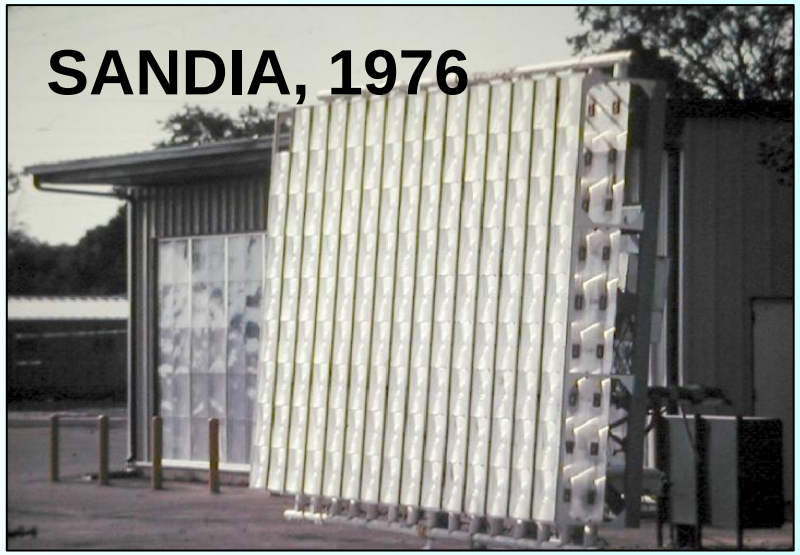
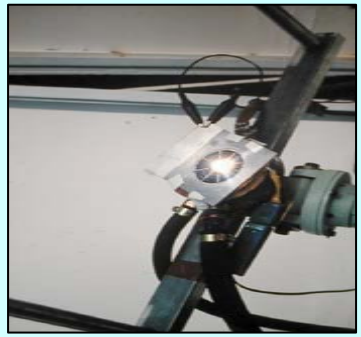
When really began the MEDIUM PV Concentration?

Sandia Array (1976) was operated at **38X** as a Point Focus system

It should not be considered MEDIUM CPV,

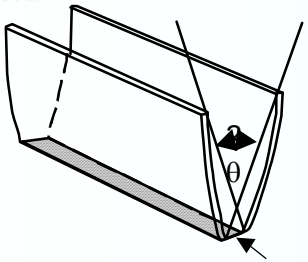
because the potential of the optical concept and the BOS requirements are like those of 300X today





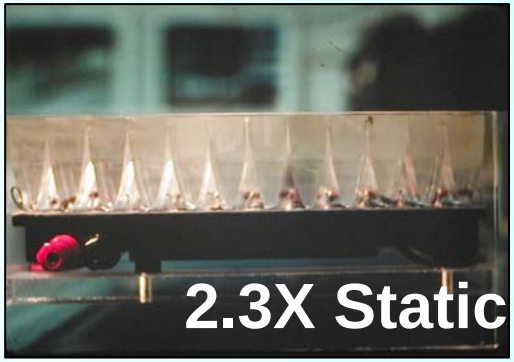
ENTECH 20X linear is what we think is "MEDIUM CPV"

The beginning of LOW-Concentration PV



Receptor (célula convencional)

$$C = \frac{n}{\text{sen}\,\theta}$$

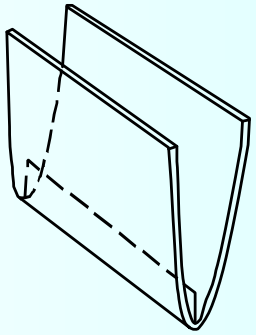


- R. Winston invented non-imaging optics and started quasi-static low CPV

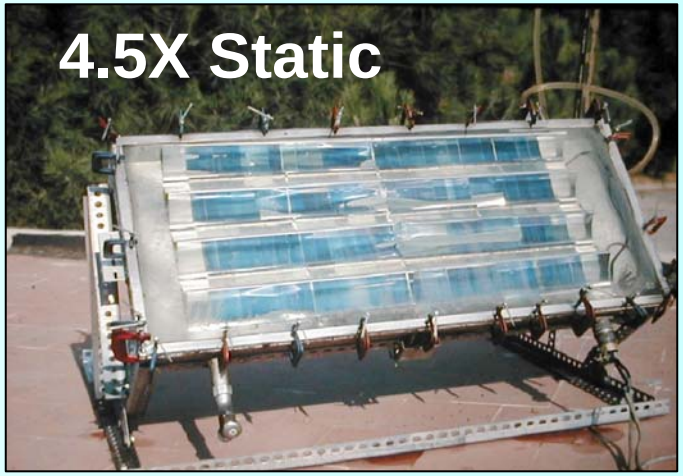
- A. Luque in Spain, (Europe), jumped to Bifacial concept doubling the chances of Static Concentrators

- As a “colateral effect”, bifacial cells allowed the creation Isofoton as PV manufacturer, European leader in 2001.

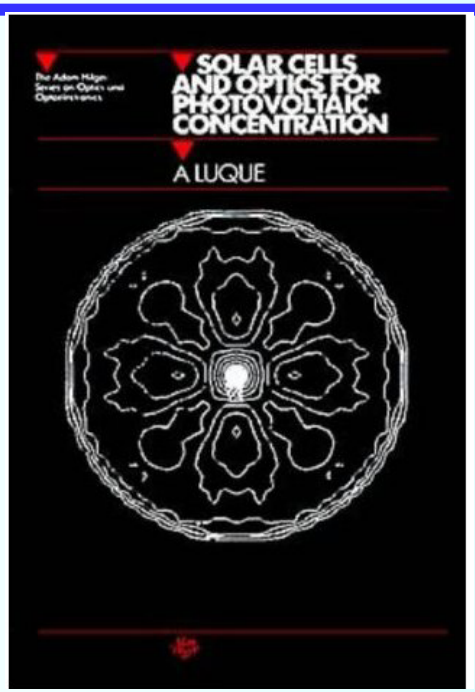
$$C = \frac{2n}{\text{sen}\,\theta}$$



Receptor (célula bifacial)



Static non-imaging in Spain



- Luque and Miñano contributed, as well as Winston & Welford did, to LOW CPV.
- Static concentration concepts based on non-imaging optics was deployed in books and practice with bifacial cells

Commercial use of static concentrator developments

- **Lessons learnt**
  - The cost reduction promised by the preceding aproaches, were about 20-33% of the current cost of flat panels at that time
  - It was never considered SUFFICIENT to start any industrial nor commercial action by the cell manufacturing companies.
- **Could it happen again with any low CPV?**
  - YES, probably cell manufacturers will not enter into low C concentration if the cost reduction is not very significant.
  - On the other hand, new companies specialy created to manufacture and commercialize LOW or MEDIUM CPV, are fully motivated and could reach very fast cost reduction advantage in short term.

- The cost level 3.5 €/W can be and must be the target to reach very soon.

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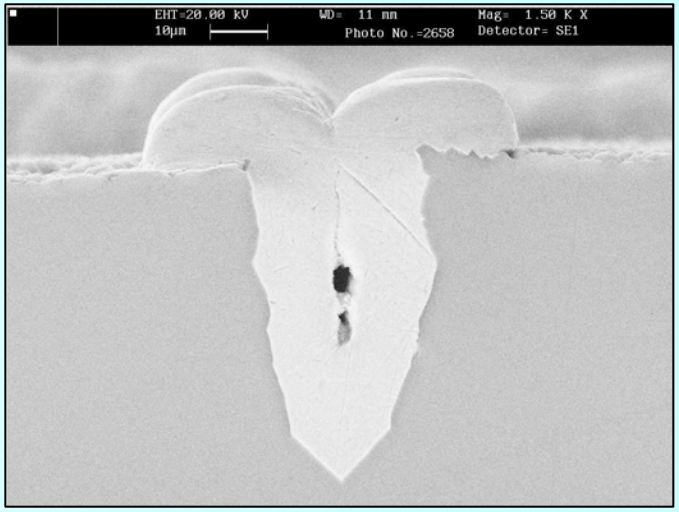
The problem of Concentrator cells scarcity

- C-Cells have been always scarce and very expensive because the performing technologies were not in production lines, except for space.



- A KEY TECHNOLOGY for Low-C and Medium C is the LGBC solar cells made by BP SOLAR
  - The also called SATURN cells can be manufactured in the same line as the conventional cells..
  - The cells are practically equipotential along all their surface and shows increasing efficiency and better performance in concentration.
  - ENTECH ordered few cells for its 20X concentrator .

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European Commission subsidizes CPV projects

- Central Europe was acquainted of the large direct radiation in Mediterranean countries when feed-in tarifs began centering the attention on PV bussinesmen

- Saturn cells become the starting base for the EUCLIDES project, the first on PV Concentration subsidized by EU.

- The mirror size was conditioned by the existing cells: effective irradiance was 2.75W/cm^2, at standard test conditions

- Tests of cell encapsulation were carried out by BP in real C-sun in Spain (6 months on a tracker, but not were done accelerated tests)

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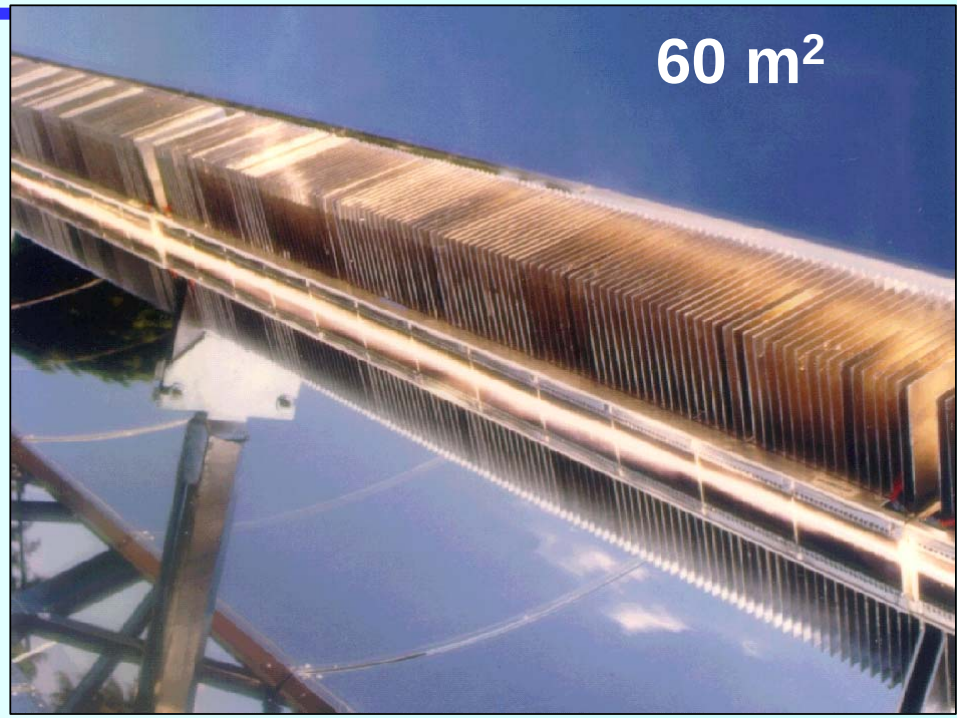
Euclides I characteristics

Power Efficiency: > 14% ;
Energy efficiency > 10%.

Modules were assembled in BPSolar Madrid.

Mirrors were made shaping aluminum plates which were previusly covered with 3M reflective film EPC 305.

Film lamination and film edge protection were critical respect to the mirror reliability : water intrusion is fatal in this technology.



- The mirror manufactured in Madrid was nearly perfect: No water has entered by the edges in 12 years.
  - Optical efficiency of single modules was 92%. Degradation becomes at the 6th year.
  - (new ECP 305 + has shown much longer life)
  - The array was considerd a succes and the forecast cost was 3.5 to 4.0 €/Wp (best cost was 7.5 €/Wp for conventional big plants that that time)

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EUCLIDES Demonstration Power Plant

- The EUCLIDES Tenerife demonstration plant ,

  480 kWp, was partialy subsidized by EC.

  World Largest in 1998

  – As we did recently in ISFOC we thougt that the real start up of a technology required that companies were forced to industrialize at significant size, not just make an array or two.

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What worked well in EUCLIDES? 1) Tracker control system

- **Made by external menufacturer, INSPIRA, spin off of UPM.**
- **It was required to pass qualification (as any electronic equipment) versus temperature, insulation, IP65, radiolectric inmunity, etc.**
- **A set of repetitive field tests were asked in contract for acceptance in adition to the previous qualification as electronic circuit:**
  - Recovery after a local blackout, end detectors reliability test, repeatable accuracy to reach any position, man-machine communication, data downloading, etc. Test were performed on the field,
- **With all this requirement nothing failed after once the company finished the initial set-up.**

INSPIRA: one axis tracking Control system (1998)

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What worked well in EUCLIDES? 2) Tracking structure

- Prototype structure was previously mounted on the factory yard.
- Bending, torsion and oscilating frequency were tested. As result of these tests the mechanical streght was incresed till reduce the natural oscilating period.
- The bending was as small as expected.

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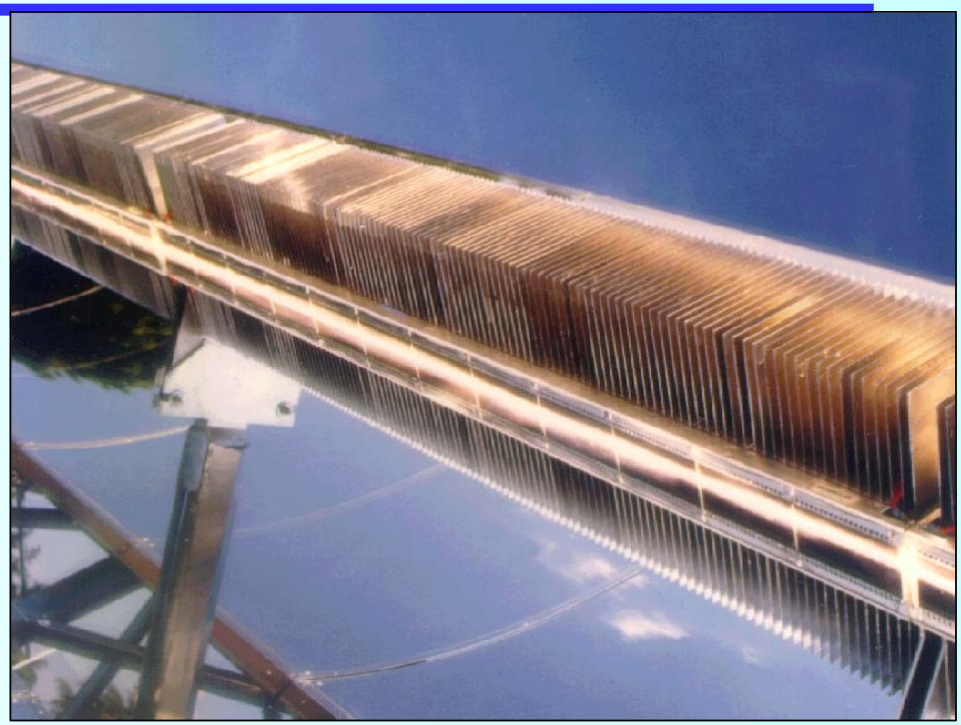
What worked well? 3) Heat sink and module gluing



- It was an evolution of the Euclides I design and was in charge of a company.
- Fabrication process was trimmed till thermal transmission was maximized.

- Sorted sampling control tests were agreed and equipment for size control was provided by manufacturer. The whole order was checked.
- Near 5% elements were rejected.

  – Gluing of modules to heat sink core performed well: just one module failed among near 2000.
  – Warning: Glue material deliveries must be checked before entering into production line

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What was partially wrong? 4) Mirrors

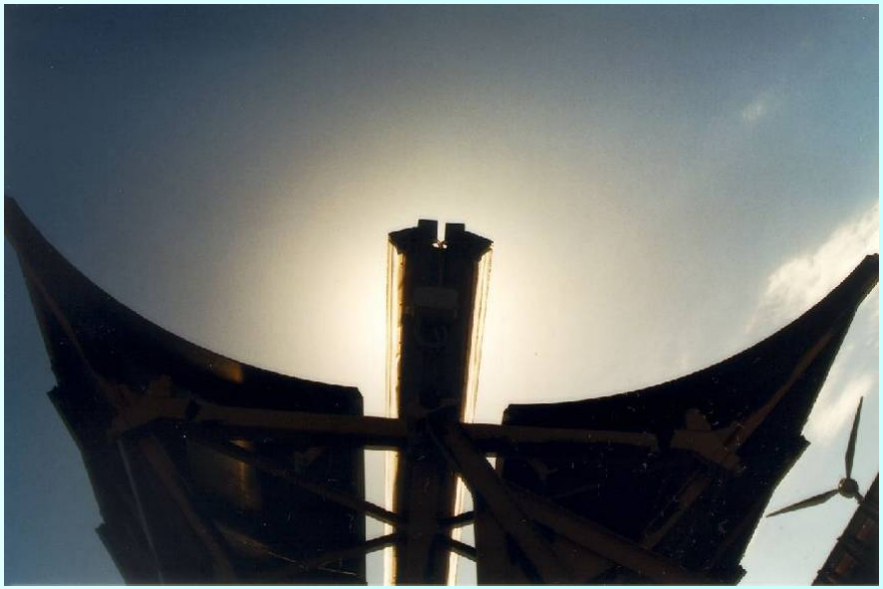
- Shaping of metal parabolic mirrors must be carried out on site to avoid high transportation costs. (Mirrors for 1MW fill 4000m^3 but before shaping only 20m^3)

– Control of this job is crucial because local people must be trained and supervised.

– Mirrored metal surfaces must be protected with suitable barrier films adequate for the site (Volcanic soil, etc)

– Wind loads on the rib junctions must be checked with mechanical standard tests.

– None of these test or actions were carried out in Tenerife. 15% of mirrors were damaged in one year.



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What was wrong? 5) Receivers

- The receiver have proved to be the weakest component of any L&M-CPV modules, because the usual contradictory requirements: electrical insulation, thermal conduction, mecanical stress, thermal stresses, all combined with large area cells.

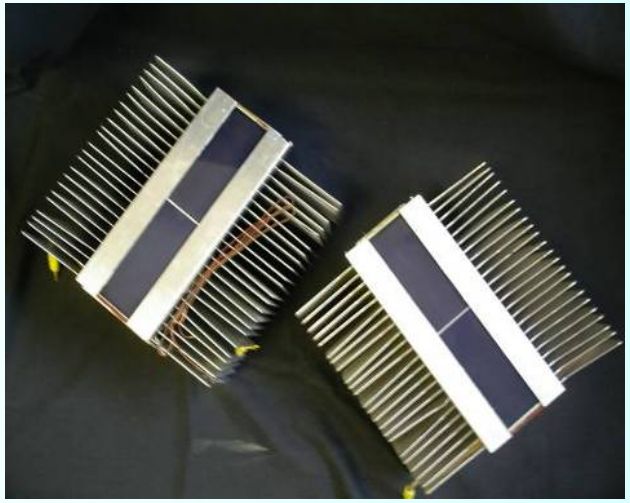
- Insulating tapes and gluing pastes although they show the neccesary characteristics at the catalog level, seems not accumulate too much experience in our CPV applications and failed within specification ranges.

- In consequence we cannot especify, nor today, what must be the correct qualification testing.
- .
- **The terrific economic impact of any receiver failure at the field pointed out the tremendous need to have an efficient qualification standard which really unveils the problems to come for any type design.**

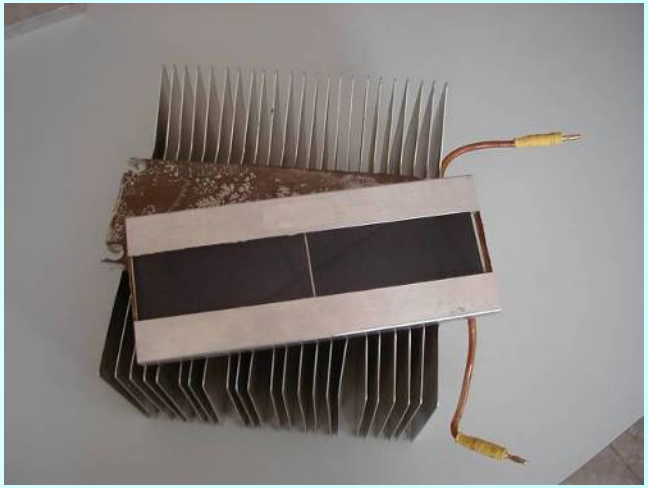
The EUCLIDES III receiver: New designs under test

- Four years ago we tried to improve the original receiver design of BP Solar that failed in Tenerife.
- The failure there (1998) was due to a combination of poor fabrication control and insuficient qualification of the receiver: the tests adopted for the proof of concept carried out at BP Solar were too soft.
- At UPM we developed new generation of receivers and produced samples for qualification under IEC62108 standard within the Ideoconte Project (EU)

EUCLIDES III Receiver



Test samples



Failure unveiled by IEC62108

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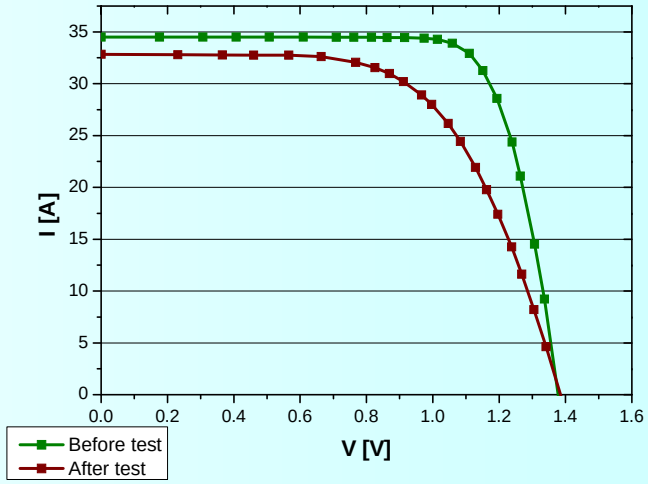
The EUCLIDES III receiver: New designs under test



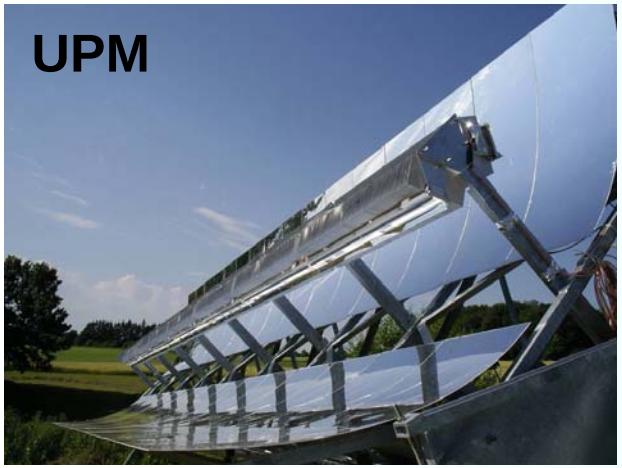
- We have selected materials that can fullfill CPV requirements according the catalog properties, but nevertheless several failed after the IEC62108 tests.
- Is the tests too hard or the standard is effectively unveiling future failures?

Before and after the thermal cycling test.

Data @ 25ºC, 20X	Before test	After test
Voc [V]	1.38	1.39
Isc [A]	34.51	32.84
Pmp [W]	36.55	27.94
Vpmp [V]	1.11	0.97
Ipmp [A]	32.93	28.92
FF [%]	76.63	61.08
Eff [%]	***17.51***	***13.38***

Several LOW and MEDIUM CPV recent proposals

- **IDEOCONTE Project (2002-2007)**
  - It was the last CPV project subsidised by EC based on Si cells, specifically on Saturn Cells from BP Solar.



EUCLIDES III
20X and 40X

ARCHIMEDES
2X and 10X (commercial)

PRIDE
Static 2.5x, facades

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Several LOW and MEDIUM CPV proposals

Univ. Lerida

Heliodynamics.

CHAPS

Buildings:
A niche for LCPV

Arontis, Sweden

SKYLINE™ solar

Manufacturer
(Ca) , USA

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Conclusions and Remarks

- HIGH CPV has become the neccesary tool to reach very high PV efficiency, up to 25% already measured on real systems. This is probably a good way towards low cost and fastest growth.
- But it is probably that L&M CPV can co-exist with the HCPV at leaast for a decade: the investements of ENTECH (USA), ARCHIMEDES SOLAR (Ge) and SKYLINE SOLAR (USA), among others seems proving that there are several coincident ideas on this. Niches of application are possible wich are different of big power plants (Building)
- Lack or scarcity of efficient concentration solar cells and a fully demonstrated encapsulating technology for large cells are the bigest problems for these approaches.
- ENTECH demosntrates from 80's that LCPV products can be reliaable.
- Field experience will be required to reach the real market in addition to pass all qualification tests.
- L&M-CPV could allow also the fast growth required by PV to supply one third of electricity demand before 2025

Thank you for your attention !

www.ies.upm.es

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EUCLIDES –THERMIE CPV Power Plant (1998)

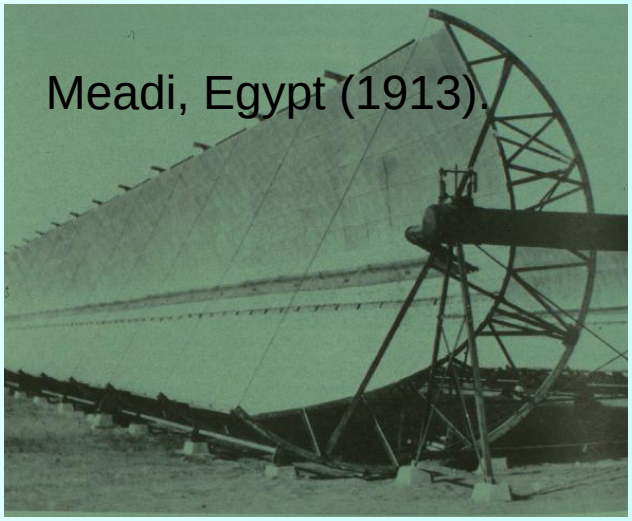
The first efficient European Low concentrator applications

– Archimedes in Syracusa (Magna Graetia, Sicily)

–Probably the level achieved with the mirrors was around 50X effective

This event anticipated,several centuries before Christ, that we could have thermal problems in the future concentrating light on solar cells or anything else.

• Parabolic trough was used in 1913 by Europeans in Egypt to produce steam, and generating electricity with a turbine. It was not PV but was medium-C, similar of several today PV and CPS approaches.



– Parabolic trough from Frank Shuman,

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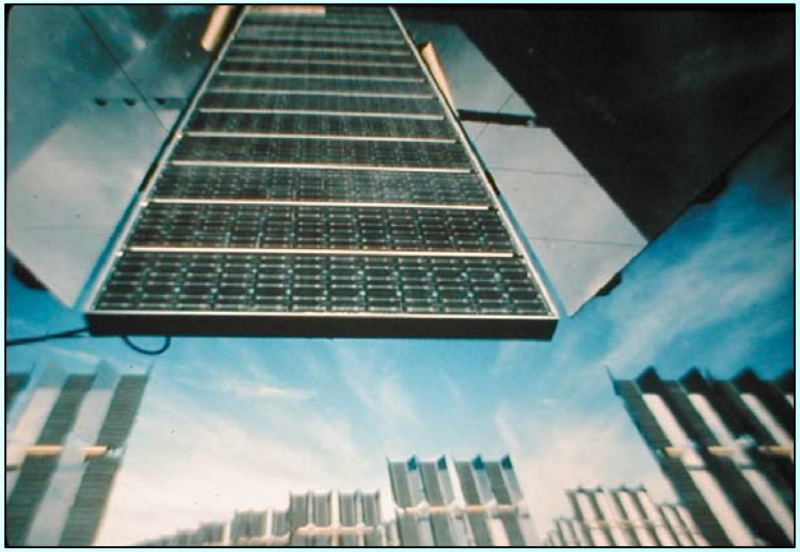
Other lessons to remember: 2X at Carrizo (CA)

- 2X concentration with flat mirrors was used at Carrizo with Conventional modules as receivers. It causes early degradation of the whole plant (about 1MWpeak was lost). Although the EVA was worse that the one used today, it was a mistake.



- That mistake has been recently repeated in EUROPE:
  Conventional modules have been used at
  Cg=2.2 X
  in a MW sized Power plant.
- (Details in a paper by E. Lorenzo in PIP)

  – This type of approaches presents extra loses caused by
  – *Double increase of cell temperature : **T loose = - 15%***
  – *Increased Joule losses : **3 Rs.Im / Vm** = - **20%***

  –The overall operation efficiency is reduced to **0.65 times** with respect to the expected resulting a net 1.3 gain but reducing the module lifetime by the overheating

  –One conclusion is that we need standards for defining an testing the power rating and the thermal properties of the modules in a fast and controlled way. (NOCT or Rth)

ENTECH demonstrations at 20X

Entech developed and deployed the leading M-CPV focusing technology on linear lenses.

They deploy the largest demonstration plants (up to 350kW)

No standards were defined for the cells or modules.